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THE INTEGRATED INTERPRETATION OF THE EARTH SURFACE IMAGES RECEIVED FROM NIMBUS-1

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The Integrated Interpretation of the Earth Surface Images Received From Nimbus-1

by B. V. Vinogradov

The original photographs transmitted to the earth by cosmonauts or in containers from orbital satellites, have an indisuptable advantage over those taken from satellites with television images because of a higher resolution and ~~also~~ the absence of distortion connected with television image transmission. Their estimated aerial resolution at a photographic scale of approximately 1:2,000,000 attains 0.1 km, and with a greater contrast of some objects--30 m. Moreover, space photographs obtained by cosmonauts are optional to a definite degree and do not cover the entire territory of the planet systematically. Therefore, to obtain regular spatial information both in the present and in the future, an analysis of the ~~Earth's~~ television images of the Earth is essential. In addition to this, one should, of course, strive to increase their resolving power to at least 0.1 km.

The first program of surveying the entire Earth surfaces was accomplished by the system of meteorological Tiros satellites. However, in view of a small resolving power and other technical defects, this program did not give significant results for the complex study of the Earth's surface. For surveying the meteorological situation as well as a series of aerial objectives, the Nimbus program was begun. The possibility of a geographical analysis of images of the Earth surface received from Nimbus has been mentioned by a series of authors [1, 5, 6, 14]. In the Nimbus program, satellites were placed

into orbit at an altitude of 800 - 1100 km. These satellites have a revolution approximately 13 times every 24 hrs. Three television cameras were set in Nimbus with a high resolving power (to 0.8 km) for day time surveying and transmitting to Earth by the AVCS and APT systems global information of the cloud cover and surface of the Earth. The HRIR infrafed sensors are used for observing beyond the cloud cover at night. A firm triaxial stabilization in relation to the Earth's surface is a great advantage of the Nimbus satellites. The optic axis of the center camera is oriented along the regional vertical with an accuracy of $\pm 1^{o}$, while the axis of the two high perspective cameras form a 35^{o} angle with the regional vertical one. Orientation fluctuations in the plane of the bank of the point tongue do not exceed $\pm 3^{o}$. The area coverage of such a triplet consisting of one vertical and two perspective images, is 2700 km in latitude and 835 km in longitude. As a result, for only one revolution (108 min) around the Earth, the Nimbus gives an image of 10% of the Earth's surface. An important advantage is the movement along a sub-polar orbit of 80 - 90^{o}. Successive orbits are about 25^{o} to the west so that for approximately 13 - 14 revolutions, the Nimbus gives an image of the entire earth's surface, which continues for approximately 24 hours. In this time, it transmits about 1300 images. The data are recorded on 35 mm film.

To clarify the possibilities of a detailed geographical study and carthographic reproduction of separate landscape components according to the Earth's images received from Nimbus, we have produced

an identification by a photograph of the Paris basin taken on Sept. 14, 1964. An interpretation was made by prints magnified to 1:1,850,000 m (fig. 1) and included an identification in the photograph of aerial objects by means of a comparison of maps in scales of 1:500,000 - 1:2,000,000 with images received from the satellite. Then an analysis was made of contours of three categories: 1) those which received a legible representation in the photograph, 2) those which received a hypothetical representation (one may make out the general trend, but it is impossible to show details) and 3) those which received no representation. Moreover, the factors were analyzed which determine the representation character of landmarks in the photograph or the absence of their representation.

The Paris basin is a plain with markers from 50 - 100 m above sea level, surrounded on the east, south and west by low elevations with heights of 200 - 400 m. This is a synclinore, consisting mainly of tertiary rocks in the central part and mellite and jurassic rocks on the outskirts. The Paris basin is situated in a broad-leafed forest zone with a wet, moderate marine warm climate [8, 9]. In the analysis of the Paris basin, the image received from Nimbus-1, we made an identification of the plant cover, soil banks, varieties of the lithological composition of bedrocks, topographical forms and elements of a hydrographical network.

Plant cover. In spite of the intense cultivation of the Paris basin landscapes, the plant cover is extremely varied. Forests of summer and winter oaks, chestnut, beech, white beech, spruce, birch,

ash and other forest varieties alternate with meadows, waste lands, river brushwood and agricultural lands. The identification was made by photographs of an early autumn appearance when the physionomical differences between aerboreal varieties are increased, while between herbal plant assemblages, they are decreased.

In the television image (fig. 1) the beech-oak forests with an admixture of spruce and birch in the Ardennes are represented by the darkest, almost black tones. These forests have the greatest density and shading. Groups of insulated white beech-oak-beech forests in the Uaz, Ardennes, and Argonne are represented by a somewhat lighter, dark gray or even-toned with a diffused edge. The groups of chestnut-oak forests, prevalent in the lowlands of the Seine river, are represented by the same dark-gray tone. These groups of forests differ only in being confined to different geographical regions. Groups of forests somewhat more rarefied and cleared of the Marne, Uaz, Ardennes and Argonne are represented by a dark gray tone with a sparse cloud-spotted texture.

Many forest areas are small in size, sporadically distributed, and alternate with agricultural lands, meadows and wastelands. Although firests do not give a completely integral image and are distinguished in small grayish patches of low contrast, they cannot be graphically outlined accurately enough and are divided on the map in the form of combinations together with other terrain features. The effect of integrating is very significant in forming the representational tone of objects in satellite photographs. So for example,

small groups of forests (2 - 4 km) with the same composition are represented by a lighter (gray) tone than the large groups (4 - 10 km) which are represented by a dark, gray tone.

In all regions of the Paris basin, there are large spaces between the forest groups occupied by an alteration of small plots of oak forests, meadows, wastelands, cultivated fields, vineyards and fruit gardens. They are represented by an integral gray, lightish-gray tone with a notable diffused-mottled texture. From these are distinguished forests of summer oak and plantings of pine, which alternate with the meadows, wastelands, fields and vineyards of Champagne Sec. These localities are represented by an integral lightish gray tone with a stronger moire texture of greater contrast. The summer oak is characterized by an earlier yellowing of the leaves and in Autumn its plantings are distinguished from winter oak by a lighter tone.

River valleys with river forests of ash, willow, alder, poplar, with meadows and small marshes, gardens are represented by narrow strips with extremely sharp borders, if the entire river complex has a width of no less than 0.5 km.

Finally, the mainly woodless grounds with meadows (natural and cultivated), wastelands, workable lands, vineyards in Piccardy, along the outskirts of Champagne Sec, on the Plateau of Bre and the lowlands of the Seine are represented by a comparatively even, lightish-gray tone.

The details of the investigation of the vegetation proved

extremely numerous (fig. 2). In the photograph, a clear differentiated image was obtained lf almost all the areas of a forest more than 2 - 4 km in size, on the map vegetations indicated in scale of 1:1,000,000 [4, 15]. Only the damp, meadow-marshy floodplains of the river Ser (Ena) and the rivers Marne, She, Ornen (Champagne Tristesse) merge in places with the image of forests (but they are distinguished by the configuration of contours). Forest groups with a probability of 0.7 (with Δ = 10%) are differentiated along the basic forest-producing species. When the features of a photo image prove insufficient, zoning comes to one's aid. For example, the white beech-oak forests of the Marne and Argonne have the same dark gray tone as the chestnut-oak forests of the Seine but are distinguished by belonging to different zones. Zoning increases the probability of identification to 0.9.

Soil cover. The soil typology of the Paris basin is not treated in sufficient detail; the soils are strongly cultivated and therefore, there are well known difficulties connected with their interpretation [3]. The soil interpretation is made by features of vegetation, relief and by the position in the landscape.

Brown forest soils are confined to oak forests located along large valleys and in the lowlands. They are differentiated into strongly podzolized soils under chestnut and white beech-oak forests on sands, and weakly podzolized soils under smaller groups of oak and beech-oak forests on marl and limestone. The brown forest soils are interpreted by dark-gray patches of forests.

Brown wooded aforested residual-carbonate soils are confined to watersheds, flat rolling plateaus and plains, for the most part woodless, here and there with small groups of oak forests. They are differentiated by geographical position on flat watersheds, by a homogenous or diffuse-spotted texture of low contrast, by the predominance of the light tone of woodless grounds and by the gray tone with a finely spotted texture of small forest sections.

Rendzinas are widespread on limestone, especially chalk and also on the steep valley slopes of large rivers. They are, for the most part, woodless, occupied by wastelands, pasture grounds and fields. The watersheds are sometimes weakly forested with summer oak and plantings of pine. Among other soil series, rendzinas are represented by the lightest tone and give light-gray strips along the valleys of deeply serrated rivers in the regions of Valois, Marne and others. In the watersheds of Champagne Sec, the rendzinas are represented by a lightish-gray tone with a marble-like texture of low contrast. The alluvial soils present an intricate complex of grays, pseudogleys, humus, interred, swamped and meadow soils. They are confined to the comparatively wide floodplains of the rivers and to the lowlands of Champagne Tristesse. They are represented by fine, dark-gray strips with extremely sharp borders, sometimes intermittent with a feather, tree-like figure. Here and there, they form elongated, beaded and lenticular expansions. In spite of the apparent confinement of the basic soil series to specific plant formations, topographic forms and rocks. The soil contours in

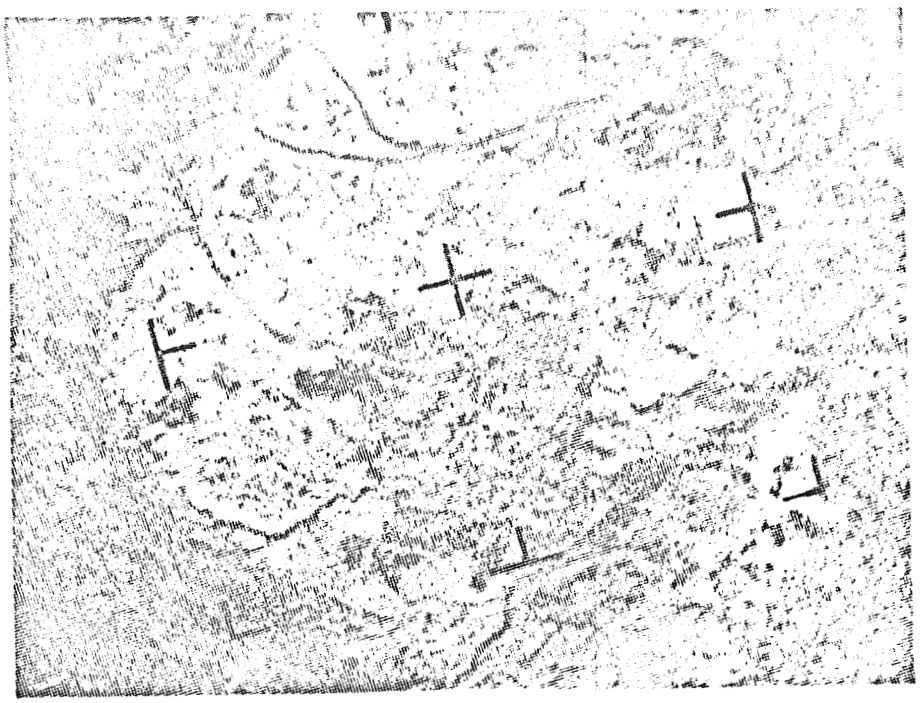

Fig. 1: Television image of the Paris Basin obtained by the central camera from the Nimbus-1 satellite, transmitted to Earth by the AVCS system and recorded on 35 mm film with a scanning rate of 1600 lines in an original scale of about 1:10,000,000. Photograph scale of about 1:2,000,000.

In spite of the apparent confinement of the basic coil series to specific plant formations, topographic forms and rocks, the soil contours in cosmic photographs cannot be identified with sufficient accuracy. Therefore, the brown soils of the podzolic series shown on map [3] are identified by 60%, the brown carbonates still less--by 40%. It is necessary to note the best discernability of azonal and intrazonal soils (just as in aerophotographs). Therefore, rendzinas are distinguished by 70% and alluviads by 80%.

Hydrographical Network. The hydrographical network of the Paris Basin is extremely dense. Here there are rivers of the first order such as the Seine; of the second order--the Uaz, Marne, Maas or Somma;

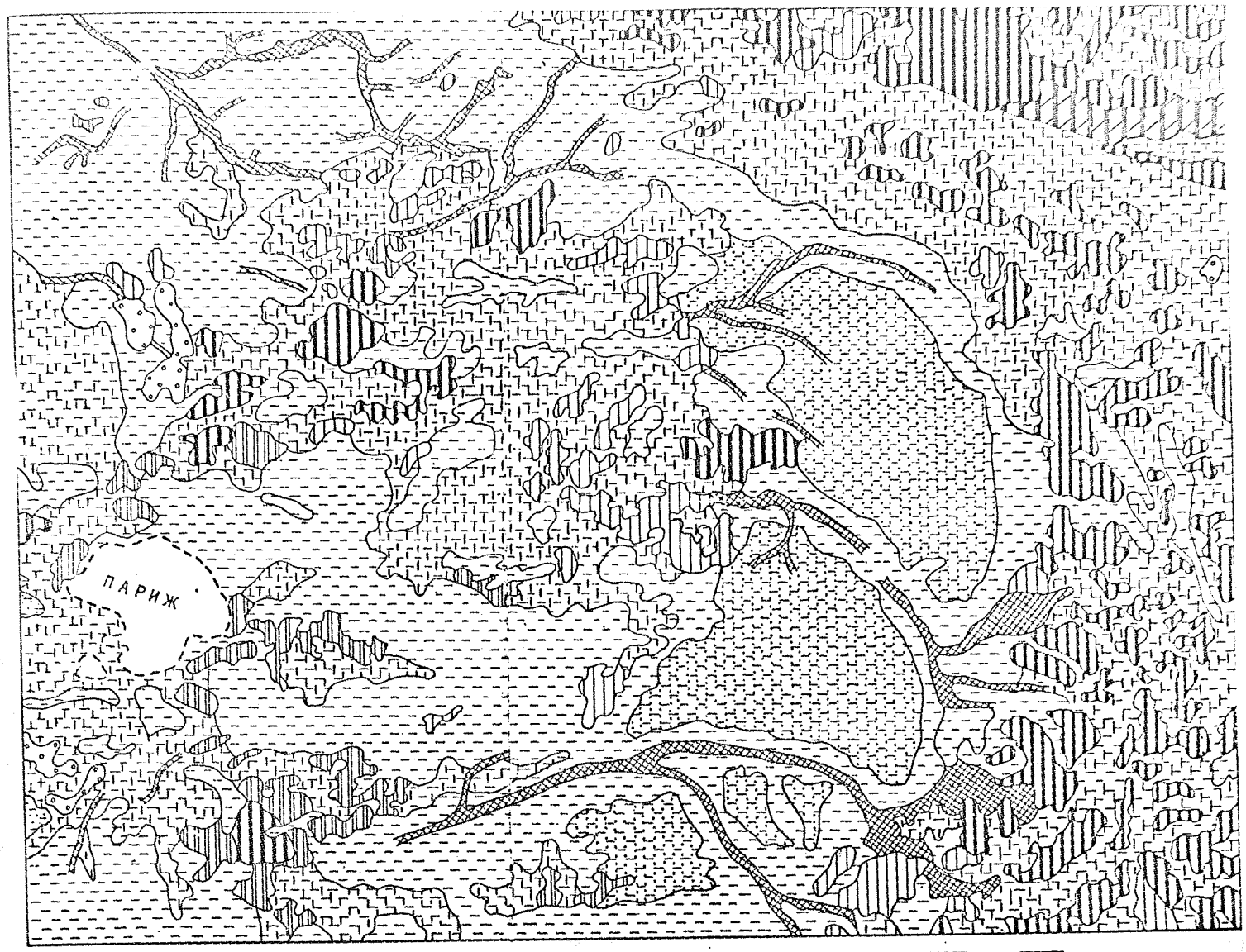

Fig. 2: Map of Paris Basin vegetation, identified in the television image received from Nimbus-1. Scale 1:1,300,000.

1--groups of white beech-beech-winter oak forests of Quercus pedunculata, quercus robur, carpinus betulus, fagus sylvatica; 2--groups of chestnut-mixed-oak forests of quercus peduculata, quercus robur, castinea satica; 3--groups of mixed oak forests of quercus pedunculata or quercus robur; 4--groups of beech-winter oak forests of quercus robur, fagus sylvatica, with a mixture of spruce and birch Picea Europaea, betula pubescens; 5--combinations of areas of mixed oak forests of quercus pedunculata or quercus robur with meadows, fields, vineyards, fruit gardens and other agricultural grounds; 6--combinations of summer oak forests of quercus pubescens, secondary plantings of pine (Pinus sylvestris) with meadows, wastelands, fields and other agricultural lands; 7--combinations of floodplain and lowland forests and brushwoods of the types Populus, alnus, fraxinus, salix with natural and cultivated meadows, grass swamps, gardens, orchards and other agricultural grounds; 8--workable fields, vineyards, fruit orchards and natural and cultivated meadows; 9--ter-

ritories devoid of natural vegetation; 10--territories with vegetation enclosed with a fine cumulus.

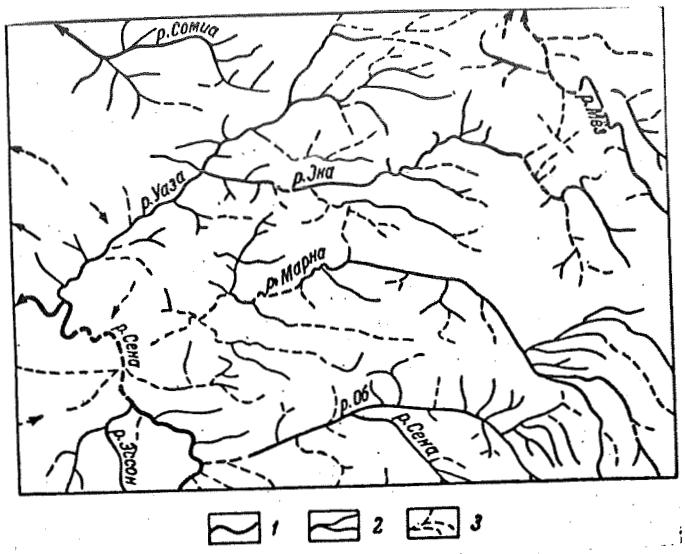

Fig. 3: Map of the hydrographical network of the Paris Basin, identified in the television image received from the AES Nimbus-1. Scale: about 1:3,000,000.

1--rivers of the first and second orders; 2--rivers of the third and fourth orders; 3--rivers hypotechnically presented.

of the third order-Ena, Ob and others. In photographs received from the Nimbus satellite, rivers of the first and second orders (fig. 3) are identified in a reliable manner. Sections of clearly expressed rivers of the first order comprise about 50%, of roughly expressed--30%, and not discerned at all, 20% in comparison with their expansion on the hydrographical network map of 1:2,500,000 m [10]. As regards rivers of the third order, their identification is significantly lower. In comparison with the hydrographical network map, these values comprised 30, 20, 50%, respectively.

The expression of a river network in photographs depends on the influence of the river valleys on the distribution of vegetation. One may present three types of river valley photo-images.

The first type of image is the comparatively clear, narrow (0.3 - 0.8 m of width of scale of fig. 1) dark-gray strips with an extremely sharp border on a light-gray background. In this case, a strip of comparatively dense river wood underbrush vegetation of willow, alder, ash and poplar alternating with meadows and swampy meadows is confined to a river valley. Such an image type is especially characteristic for the river valleys laid in the marl limestone of Champagne Sec. The second type of image is light-gray, unclear, wide (1 - 3 mm in width to scale of fig. 1) strips with a narrow floodplain which is not represented in the photograph and with steep, mainly woodless slopes have such an image. Such are the river balleys on the marls and sands of the Marne hills. River valleys occupied by settlements, plowed fields, vineyards and other agricultural grounds are also represented by a lighter tone than the surrounding oak, beech and white beech forests. The valley in Argonne has such an image type.

The third type of river valley image is the comparitively sharp borders of groups of patches with a dark gray tone. Such an image type is characteristic for river valleys having an asymmetrical structure which determined the contrast of dark forested and light woodless slopes or rivers flowing along the borders of geological formations which set off fields of bed rock occupied by forests from rocks unsuitable for a forest and occupied by agricultural grounds. According to such an image in the satellite photograph a large part of the Marne river valley is identified, which separates

the mainly woodless lowlands of the Piccardy region, composed of sands and partly of clays from several hills disconnected and covered with forests of Valois limestone.

An image of the river network is absent in photographs in those cases where the vegetation of valleys is morphologically analogous to the vegetation of slopes and watersheds. Thus, it is difficult to discern the valleys in the Ardennes where both the valleys and watersheds are forested. The illustration of the hydro-network disappears where natural vegetation is absent, as in the suburbs of Paris and within the city itself. Topographic forms, if they are not connected with changes in vegetation, are not expressed in the photograph. Even valleys with steep precipitous slopes with an incission depth of 100 m and more in the absence of vegetation indicators do not obtain a definite image in photographs.

Ridge-cuesta Topography. Cuesta topography is extremely characteristic for the peripheral regions of the Paris Basin. The slant of strata to the center of a synclinore is comparatively small, but cuestas attain very impressive heights (100 m and more).

As a rule, all cuesta ridges are expressed in a photograph in view of the more or less sharply curved borders of various landscape vegetation combinations. Depending on the kind of rocks located on the peak and at the foot of the cuesta ledge, various combinations of tones are observed along the sides of the cuesta ledge lines. One may distinguish two main variants of cuesta ridge expressions.

The first cuesta ridge image type is a dark tone at the highest

points and a light tone at the foot of the cuesta, characteristic for contents of marl and sands on which grow more or less dense forests of oak and beeck, with chalks, for the most part woodless, occupied by wastelands, meadows and plowed fields. The well known bench, Isle de France, serves as an example of such a cuesta.

The second type of image is a lighter tone at the height of the cuesta contiguous with a darker tone at its foot and the farther away plain. Such a correction of tones is characteristic for contacts of the dry woodless chalks of the cuesta's height and the plains, occupied by meadows and oak beech forests at its foot which is composed of marls, clays and sands. The eastern cuesta between Champagne Sec and Triestesse, which is comparatively low (to 50 m), but very well expressed in the landscape and photograph, serves as an example of such a cuesta.

In the photograph from Nimbus-1 are reflected all the cuesta ridges (with an interpretation error of $\pm$5%, fig. 4), indicated in the geomorphological map of the Paris Basin to a scale of 1:400,000 [2] and even more exactly than in the structural map 1:2,500,000 [10].

An attempt was made to subdivide cuestas according to groups of height: $<$ 50, 50 - 100, $>$ 100 m. Cross height indicators are fixed. A sharper tone contrast is characteristic for high cuesta ridges. But in addition, cuestas of the first variants described above (with darker heights and lighter at the foot) have more significant heights ($>$100 m) than those of the second variant (with a lighter height and darker foot) ($<$ 50 m). Ridges with diffused borders have heights of $<$ 100 m, while low expansion ridges, ridge

terminations and ridges which conflict with basic structural illustrations are still lower (< 50 m).

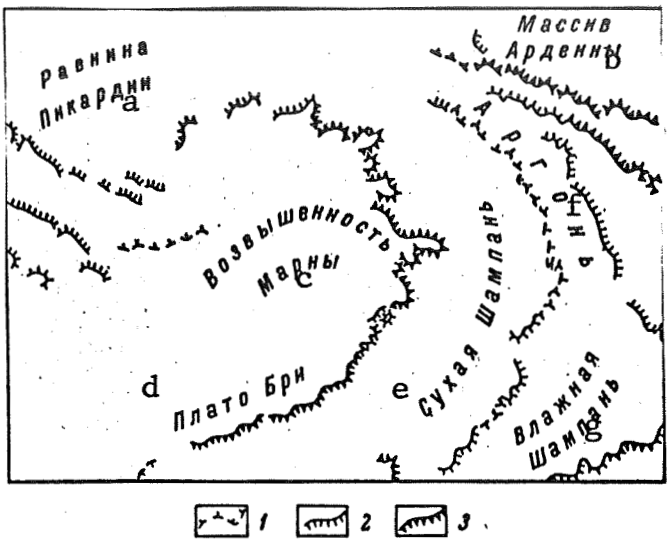

Fig. 4: Map of cuesta topography of the Paris Basin, identified in the television image received from the Nimbus-1. Scale is about 1:3,000,000.
1--cuestas less than 50 m in height; 2--cuestas 50 - 100 m in height; 3--cuestas more than 100 m in height.
a--Piccardy Plains; b--Ardennes Massive; c--Marne Elevation; d--Bri Plateau; e--Champagne Sec; f-Argonne; g--Champagne Tristesse.

Lithological composition of Mountainous Rock. The lithological composition of mountainous rocks influences the topography, the hydrographical network, the plant cover and is identified in satellite photographs according to these features. Under conditions of a humid climate, vegetation serves as the main indicator of lithology.

The metamorphized sandy shales, to which are confined the densest white beech-beech-oak forests with a mixture of spruce and birch, form an elongated group of dark tone which envelopes the Ardennes from the south and west. The intricate complexes of sands, marls and clays of the paleogene (the Marne elevation) and of the lower Cretacious period (northern Argonne, Champagne Tristesse), occupied

by comparatively large forest groups, are represented integrally by a dark-gray tone with a cloud-spotted texture. Shales of the lower Carbon and Devonian periods in the Ardennes, clays of the lower Jurassic period in the valleys of the rivers Mez, Sher, limestones of the upper Jurassic period of Southern Argonne, limestones, sands and marls of the paleogene period of Uaz, and Marne are represented integrally, by a gray tone and also with a cloud-spotted texture, but less solid. Rock of the Cretacious period with basic plantings and forests of summer oak are well distinguished by a light gray tone with specific moire illustration. Finally, limestones and marls of the Paleogenic period and chalks of the upper Cretaceous period, mainly woodless and occupied by agricultural grounds are represented by light-gray with sharply prominent dark narrow strips of river valleys on this background.

Contacts of different lithological formations are identified in the photograph, mainly by corresponding boundaries of landscape vegetation compositions. In a comparison of the photograph (fig. 1) with a geological map of France in a scale of 1:2,500,000 in [13], it was established that in the satellite photograph, about 60% of the lithological boundaries (fig. 5) were represented clearly enough. If one excludes from the number of compared formations, the Quartenary alluvial sands, which were not reflected in the interpretation only for reasons of graphic generalization, then the fraction of lithological boundaries identified in the photograph increases to 75%. Moreover, about 10% of the lithological boundaries were carried

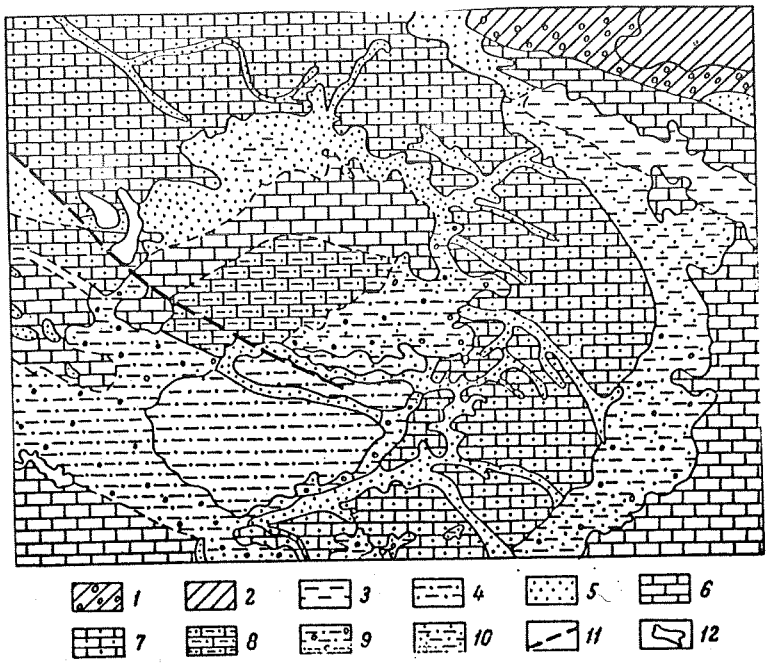

Fig. 5: Map of lithological formations of the Paris Basin, identified in the television image received from the Nimbus-1. Scale is about 1:2,700,000.
1--sandy shales of the Silurian and Cambrian Periods; 2--shales of the lower Carbon and Devonian Periods; 3--clays of the lower Jurassic Period; 4--Tertiary marls; 5--sands of the lower Cretaceous, upper Cretaceous Tertiary and Quaternary Periods; 6--Limestones of the Lower and Higher Tertiary and Cretaceous Periods; 7--chalks of the upper Cretaceous Period; 8--marl limestones of the tertiary Period; 9--marls and sands of the lower and higher Cretaceous Periods; 10--Clays and sands of the lower and upper Cretaceous Periods; 11--techtonic break; 12--clouds concealing the Earth surface.

out conditionally, i.e. their general trend was determined, but small details remained unexplained. Finally, 15% of the boundaries were not identified in the photograph. Together with the river sands, they were not reflected in the interpretation scheme. In conclusion, one should note that age boundaries are identified well only if they coincide with the lithological boundaries (as for example, between the Cretaceous and Paleogenic Periods). In many cases in the absence of lithological contacts, the geological boundaries cannot be identified with sufficient accuracy (for example, between the

lower and upper Cretaceous Period). In general, the extent of the boundaries of geological formations is much lower than the lithological (about 50%).

CONCLUSION

As is evident from the above presentation, the television images of the earth received from satellites to a scale greater than 1:10,000,000 may be used for the preliminary interpretation with the construction of field and complex maps of small scale 1:1,000,000 - 1:3,000,000. The amount of details of a special map reflected in such photographs will vary from 50 - 100%. Thanks to well known generalization, it is possible, according to satellite photographs to construct small scale complex maps with particular success. The wide use of vegetation indicators for mapping various landscape components is a characteristic of photograph interpretation of humid zones.

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